US010429709B2

(12) United States Patent
Yonemura et al.

(10) Patent No.: US 10,429,709 B2
(45) Date of Patent: Oct. 1, 2019

(54) LIQUID CRYSTAL PANEL, LIQUID CRYSTAL DISPLAY DEVICE INCLUDING LIQUID CRYSTAL PANEL, AND METHOD OF MANUFACTURING LIQUID CRYSTAL PANEL

(71) Applicant: **Mitsubishi Electric Corporation**, Tokyo (JP)

(72) Inventors: **Koji Yonemura**, Tokyo (JP); **Hiroshi Umeda**, Tokyo (JP); **Kazunori Okumoto**, Tokyo (JP)

(73) Assignee: **Mitsubishi Electric Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 206 days.

(21) Appl. No.: **15/702,269**

(22) Filed: **Sep. 12, 2017**

(65) **Prior Publication Data**

US 2018/0004024 A1 Jan. 4, 2018

Related U.S. Application Data

(62) Division of application No. 14/850,482, filed on Sep. 10, 2015, now Pat. No. 9,804,469.

(30) **Foreign Application Priority Data**

Sep. 26, 2014 (JP) 2014-195953

(51) **Int. Cl.**
G02F 1/1335 (2006.01)
G02F 1/139 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02F 1/1393*** (2013.01); ***G02F 1/133634*** (2013.01); *G02F 1/133707* (2013.01); *G02F 2001/133531* (2013.01); *G02F 2001/133749* (2013.01); *G02F 2001/133773* (2013.01); *G02F 2001/134372* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0254716 A1 12/2004 Ino et al.
2009/0115940 A1 5/2009 Ito
(Continued)

FOREIGN PATENT DOCUMENTS

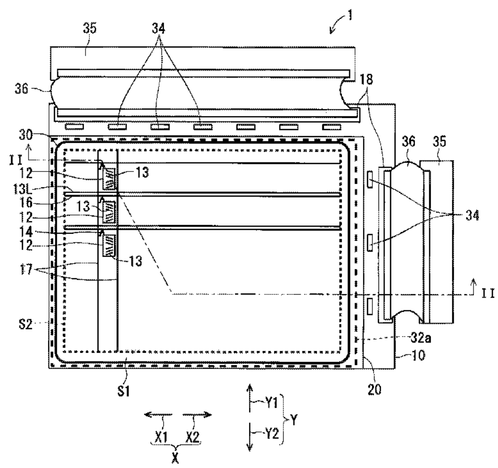
JP H04-338732 A 11/1992
JP 2003-087688 A 3/2003
JP 2007-047204 A 2/2007

Primary Examiner — Richard H Kim
(74) *Attorney, Agent, or Firm* — Studebaker & Brackett PC

(57) **ABSTRACT**

A pretilt angle of a liquid crystal molecule on the side of an array substrate is formed such that the liquid crystal molecule goes away from the array substrate in a direction to the left when viewed from a position facing a display surface of a liquid crystal panel. The pretilt angle on the side of a counter substrate is formed such that the liquid crystal molecule goes away from the counter substrate in a direction to the right when viewed from a position facing the display surface. The directions to the left and the right define a direction X corresponding to a horizontal direction of the liquid crystal panel. A direction of a delay phase axis of a biaxial phase difference film is arranged in a position rotated anticlockwise in an angular range from over 0° to 1° from the direction X.

3 Claims, 10 Drawing Sheets



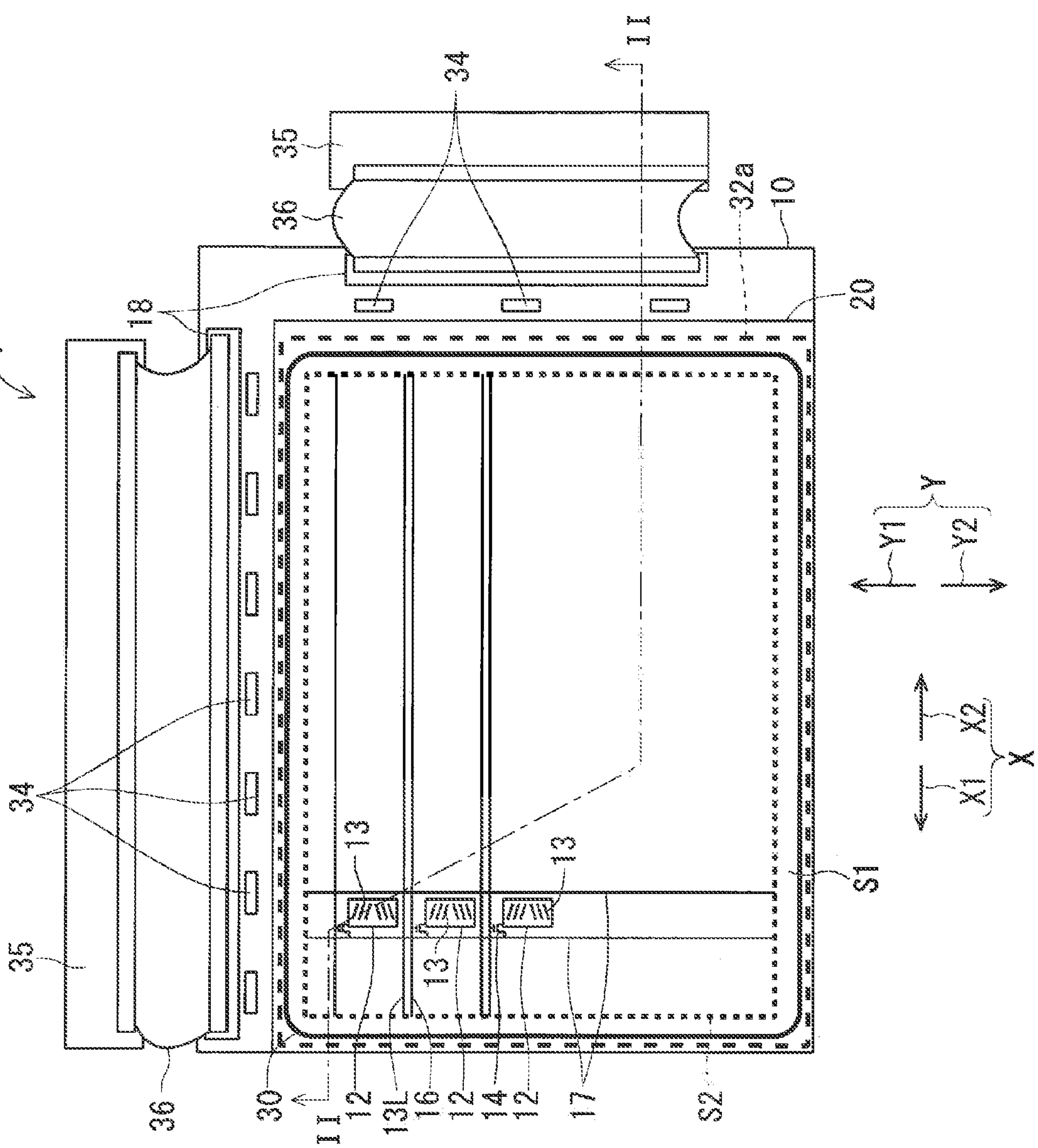
(51) **Int. Cl.**

G02F 1/13363	(2006.01)
G02F 1/1343	(2006.01)
G02F 1/1337	(2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0174846	A1	7/2009	Ito
2014/0327862	A1	11/2014	Hatsusaka et al.



F I G . 1

FIG. 2

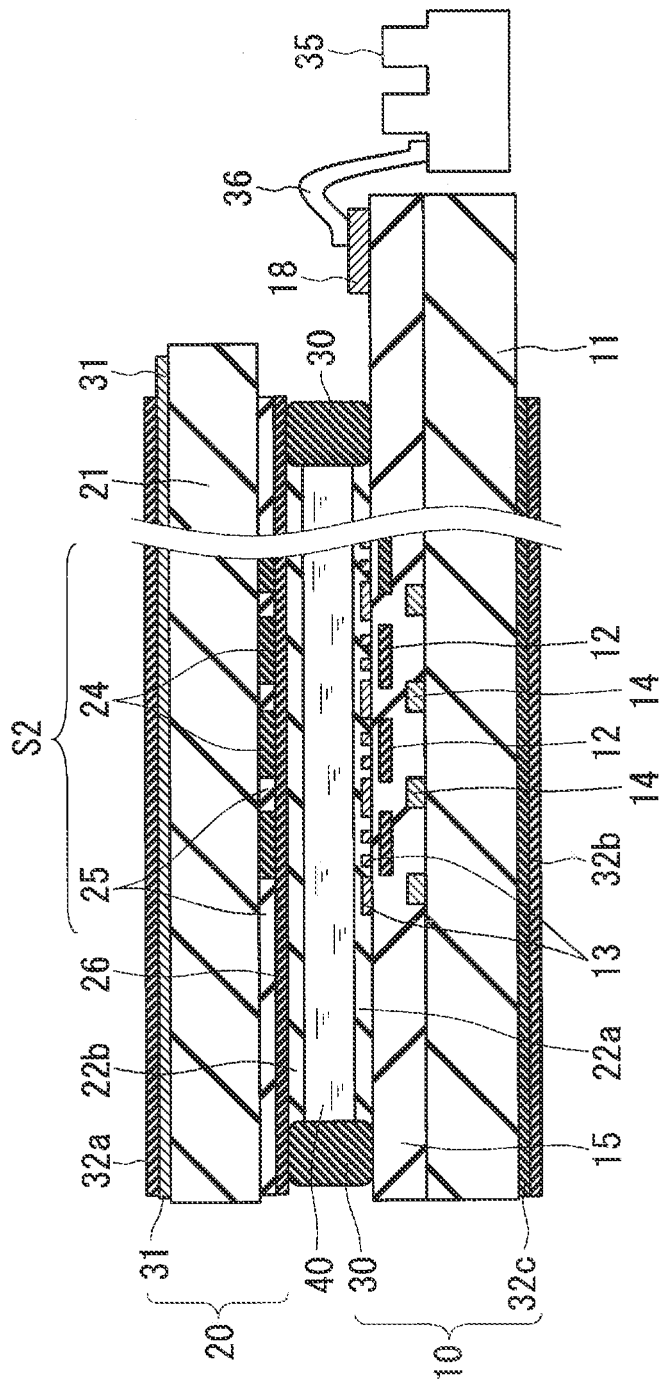

35
36
18
31
30
21
11
S2
24
12
14
12
14
25
32b
13
26
22b
22a
32a
15
31
40
30
32c
20
10

FIG. 3

Prior Art

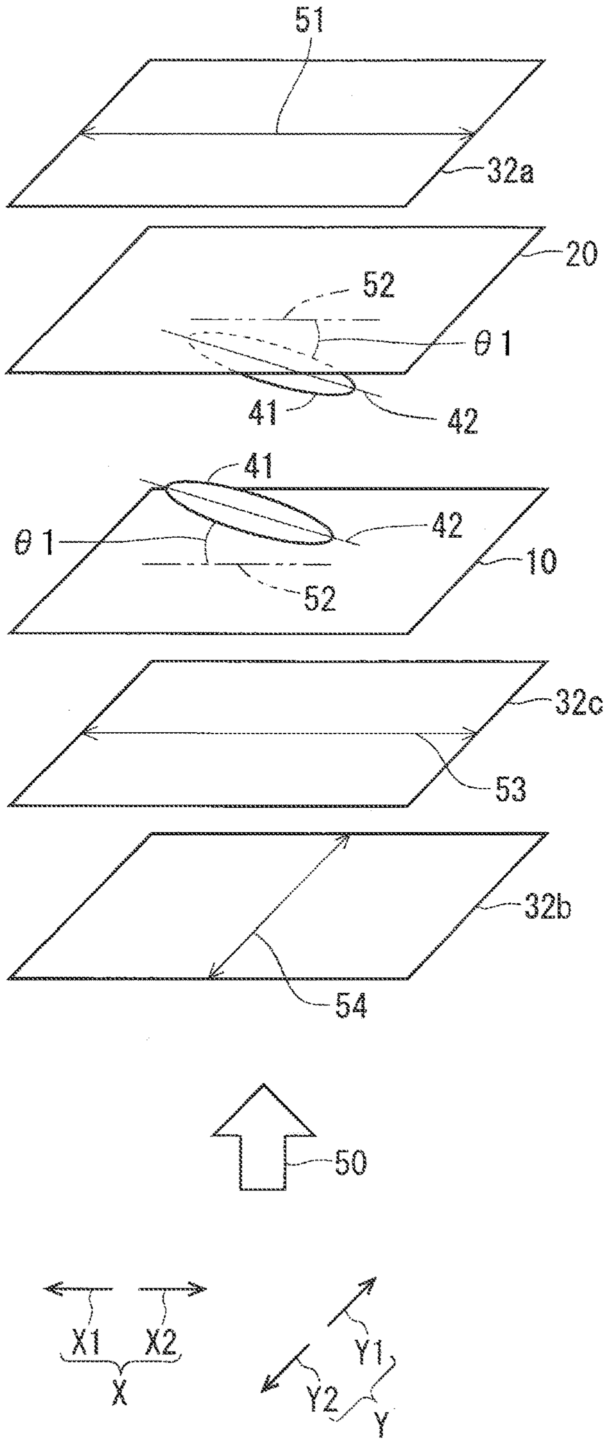


FIG. 4

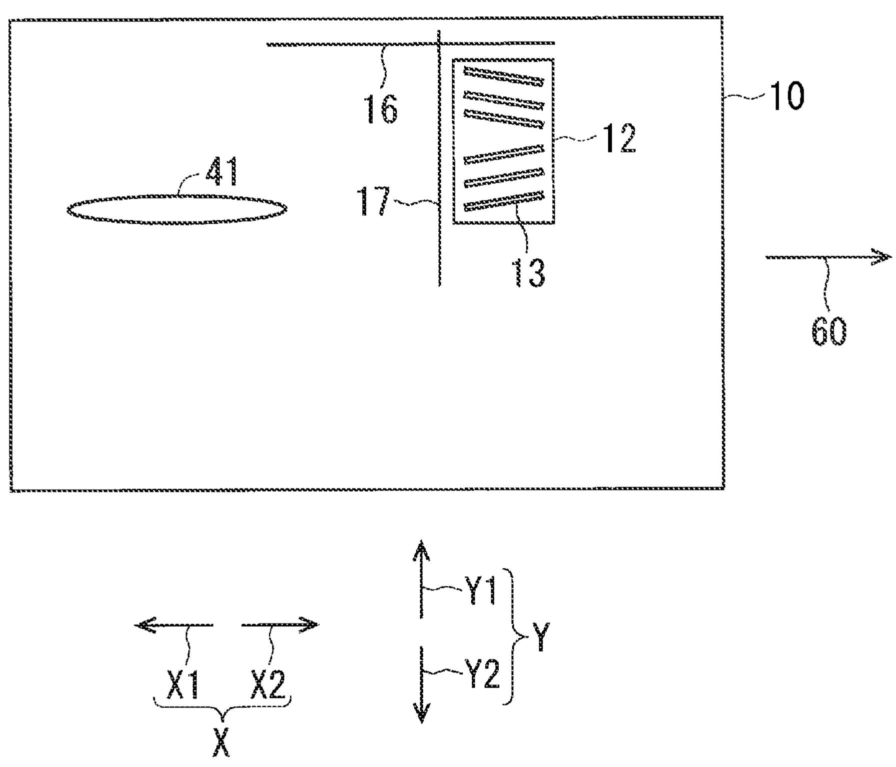
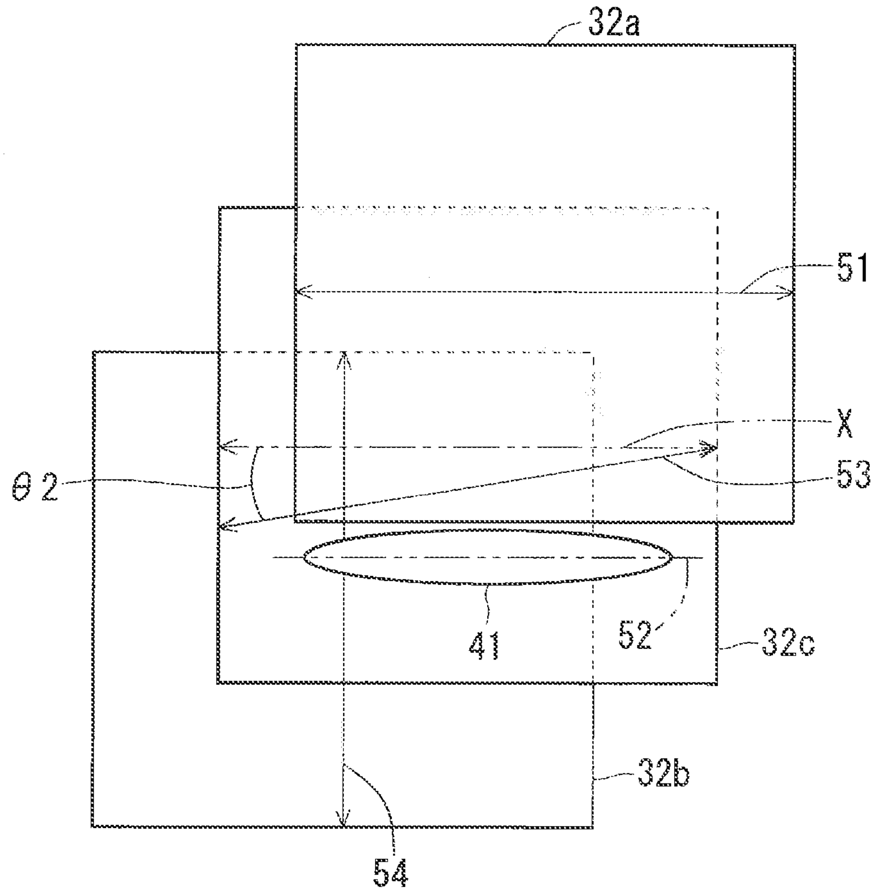
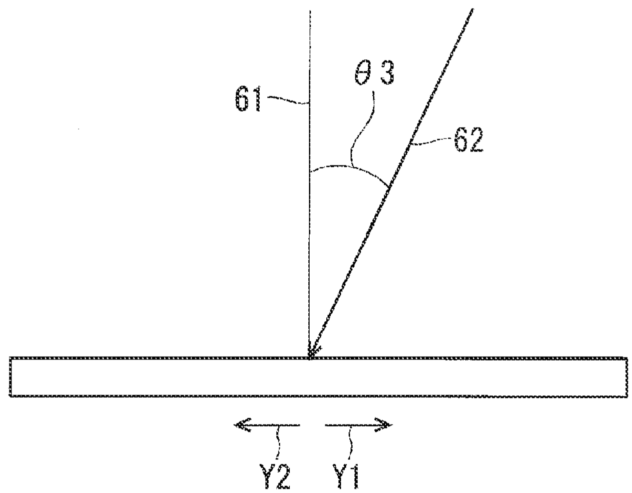


FIG. 5



F I G. 6


61
θ3
62
Y2
Y1

F I G. 7

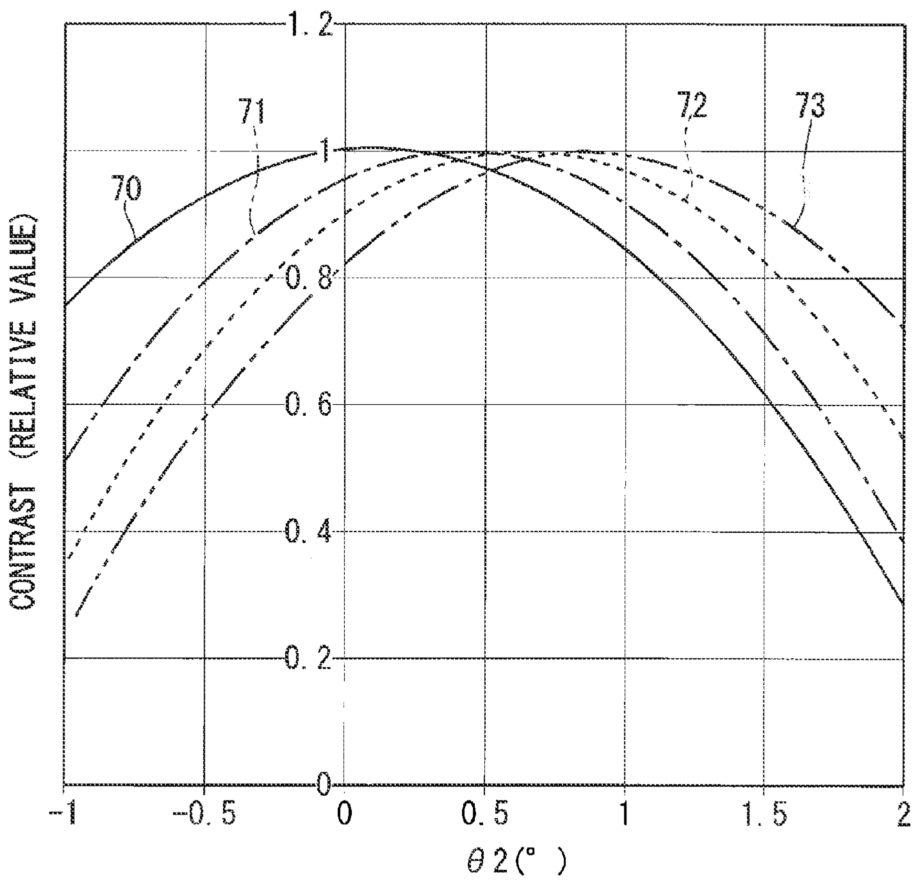
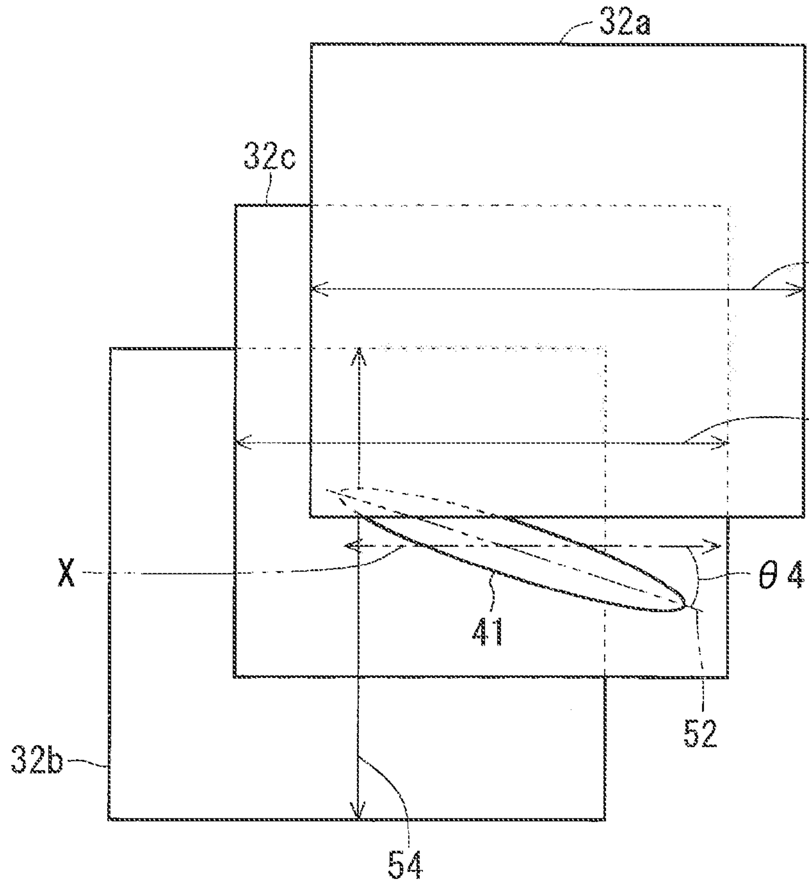
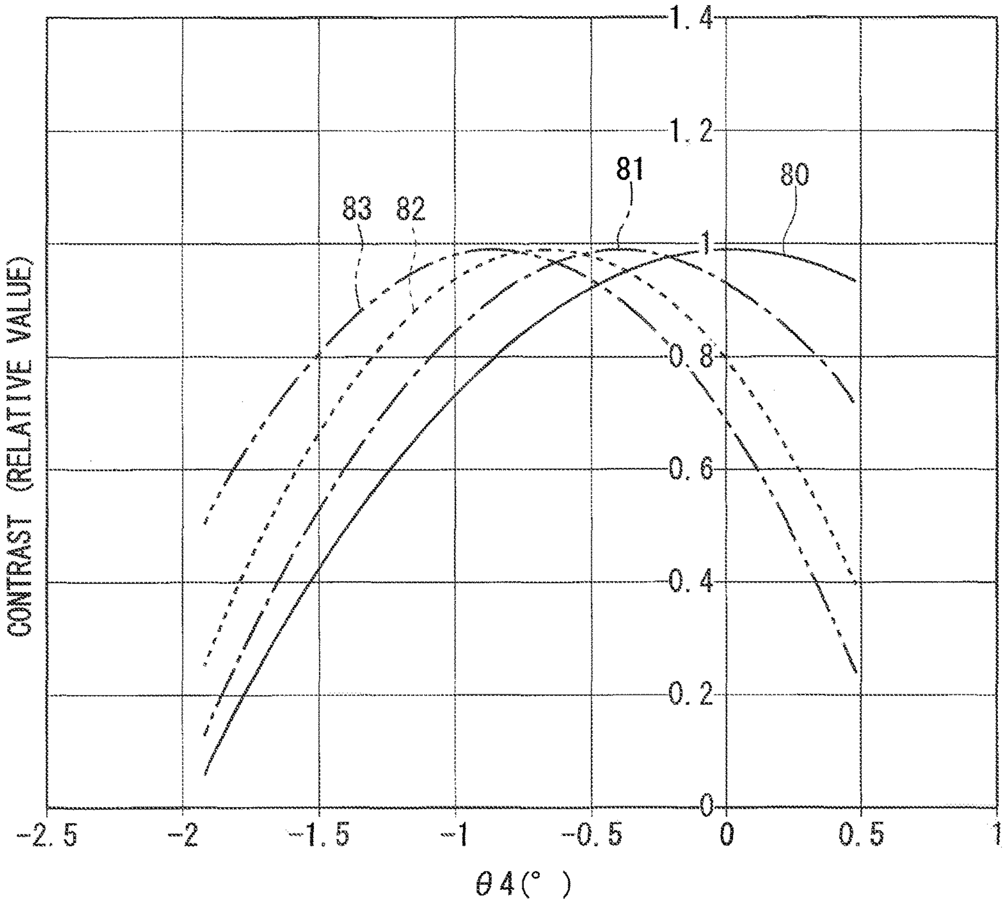

1.2
1
0.8
0.6
0.4
0.2
0
70
71
72
73
CONTRAST (RELATIVE VALUE)
-1
-0.5
0
0.5
1
1.5
2
θ2(°)

FIG. 8



F I G. 9



1.4
1.2
1
0.8
0.6
0.4
0.2
0
83
82
81
80
CONTRAST (RELATIVE VALUE)
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
θ4(°)

FIG. 10

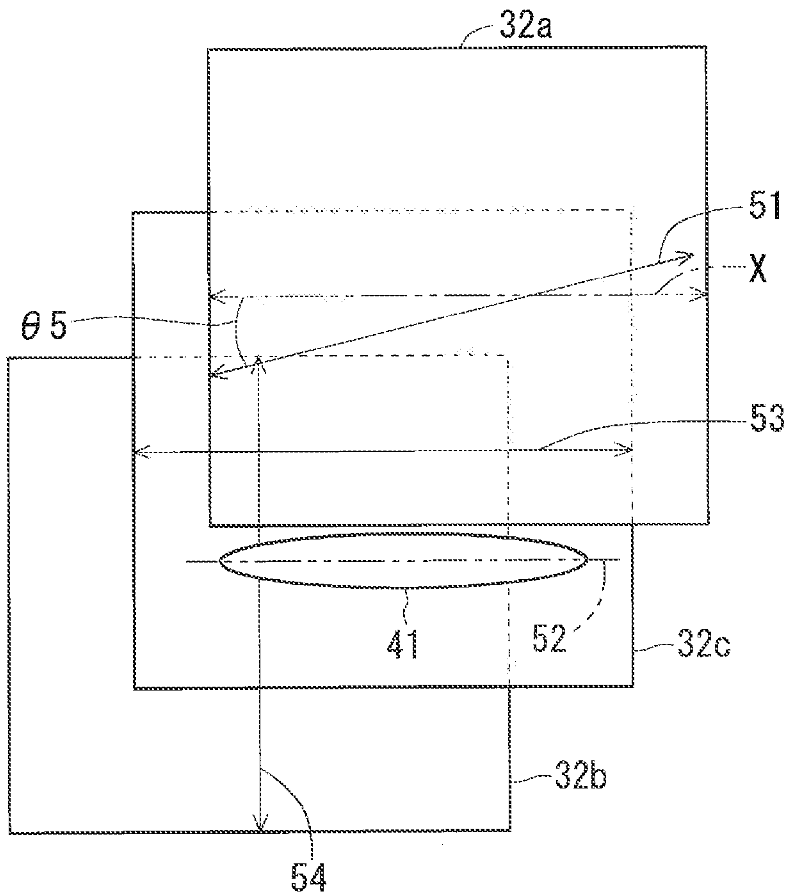
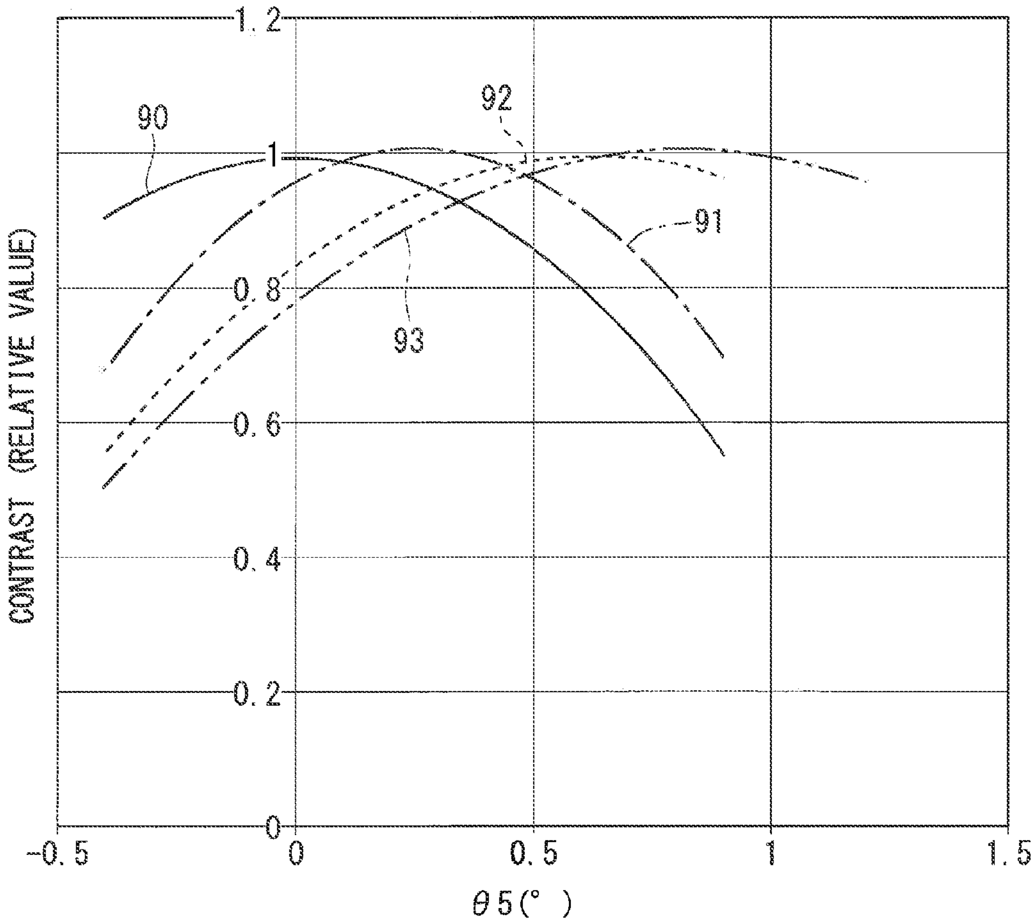


FIG. 11


1.2
1
0.8
0.6
0.4
0.2
0
-0.5
0
0.5
1
1.5
θ5(°)
CONTRAST (RELATIVE VALUE)
90
91
92
93

LIQUID CRYSTAL PANEL, LIQUID CRYSTAL DISPLAY DEVICE INCLUDING LIQUID CRYSTAL PANEL, AND METHOD OF MANUFACTURING LIQUID CRYSTAL PANEL

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a liquid crystal panel, a liquid crystal display device including the liquid crystal panel, and a method of manufacturing the liquid crystal panel.

Description of the Background Art

A liquid crystal display device is used for example as a display device of a car navigation system to be installed on a vehicle, for example. The liquid crystal display device installed on a vehicle is viewed from a driver's seat or a front passenger's seat, so that it is inevitably viewed from above. Thus, regarding the liquid crystal display device to be installed on a vehicle, adjusting a viewing angle range is required so as to optimize optical characteristics such as contrast characteristics when the liquid crystal display device is viewed from above.

A technique of adjusting a viewing angle of a liquid crystal display device in a range preferable for a device to be installed on a vehicle is disclosed in Japanese Patent Application Laid-Open Nos. 4-338732 (1992), 2003-87688, and 2007-47204, for example.

Japanese Patent Application Laid-Open No. 4-338732 (1992) discloses a twisted nematic (abbreviated as TN) liquid crystal display element characterized in that a twist angle of a liquid crystal is set from 70° to 88°, a phase difference (retardation) of a liquid crystal cell is set from 0.30 to 0.38 μm, and an angle of an alignment direction of the liquid crystal relative to a polarization axis of a polarizing plate is set from 0° to 10° or from 90° to 100°.

Japanese Patent Application Laid-Open No. 2003-87688 discloses setting brightness or contrast to vary by about 20 dB (ten times) or less in each of a range from the center to the right to an angle of about 40° and a range from the center to the left to an angle of about 40° with the intention of optimizing visibility from a driver's seat and a front passenger's seat with a liquid crystal display device arranged in the center of the front side of the inside of a vehicle. Japanese Patent Application Laid-Open No. 2003-87688 also discloses setting brightness or contrast to be reduced by about −20 dB or more in each of a range from the center to the right to an angle of about 40° or more and a range from the center to the left to an angle of about 40° or more with the intention of preventing reflection of a displayed image in right front door glass and left front door glass.

Japanese Patent Application Laid-Open No. 2007-47204 discloses a liquid crystal display device with a polarizing reflection plate arranged between a backlight unit and an array substrate. The polarizing reflection plate includes an isotropic medium layer made of an isotropic medium and an anisotropic medium layer stacked on the isotropic medium layer and having refractive index anisotropy. The anisotropic medium layer is made of an optically uniaxial medium. An average direction of the optical axis of the anisotropic medium layer is tilted from a direction of a normal to the polarizing reflection plate and a plane direction of the polarizing reflection plate.

As described above, the techniques of Japanese Patent Application Laid-Open Nos. 4-338732 (1992) and 2003-87688 are to optimize a viewing angle range of a liquid crystal display device in two directions, a direction to the right and a direction to the left. The technique of Japanese Patent Application Laid-Open No. 2007-47204 is to filter display light to be emitted upward with the intention of preventing reflection of the light in an upward direction and a downward direction of the liquid crystal display device, particularly reflection of the light in a windshield.

A liquid crystal display device to be installed on a vehicle is required to achieve a high level both in reducing power consumption in consideration of installation on an electric vehicle and making high-quality display with excellent brightness and contrast characteristics. This brings about an increasing need to optimize visibility in a direction slightly above a direction toward the front of a liquid crystal panel, particularly visibility at a viewing angle of about 20° that is to be satisfied at the expense of degradation of visibility for example from a lower side not used as an actual viewing position inside a vehicle. Thus, the techniques disclosed in Japanese Patent Application Laid-Open Nos. 4-338732 (1992), 2003-87688, and 2007-47204 leave room for improvement.

Like the techniques disclosed in Japanese Patent Application Laid-Open Nos. 2003-87688 and 2007-47204, simply adding an optical component such as a polarizing plate or a wave plate to a liquid crystal panel for filtering or changing an optical path brings about the following problems.

As an example, adding an optical component to cause filtering action brings about the problem of reduction in efficiency of use of light. Adding an optical component not to cause filtering action does not bring about the problem of reduction in efficiency of use of light but it brings about the problem of cost increase.

According to a method of compensating for a viewing angle using a phase difference film as a wave plate, failing to make a delay phase axis of the phase difference film as designed due to manufacturing variations or the like results in a deviation from intended optical compensation. This brings about a problem such as a large deviation of a viewing angle from a range preferable for a liquid crystal display device to be installed on a vehicle.

A liquid crystal display device of a fringe field switching (FFS) system as one of the systems of liquid crystal display devices achieves relatively high efficiency of use of light and a relatively wide viewing angle range. Thus, the FFS liquid crystal display device has been installed in more vehicles. The FFS liquid crystal display device of a conventional technique inherently provides a wide viewing angle range. Thus, a viewing angle has not been optimized by being adjusted finely in a range preferable for a liquid crystal display device to be installed on a vehicle.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a liquid crystal panel, a liquid crystal display device including the liquid crystal panel, and a method of manufacturing the liquid crystal panel capable of achieving preferable viewing angle characteristics when the liquid crystal panel is viewed from a driver's seat or a front passenger's seat of a vehicle even in the presence of manufacturing variations.

A liquid crystal panel of the present invention includes an array substrate, a counter substrate arranged to face the array substrate, and a liquid crystal layer interposed between the array substrate and the counter substrate. The array substrate includes multiple switching elements arranged in a matrix, a pixel electrode connected to the switching elements, and a counter electrode capable of forming a fringe electric field between the counter electrode and the pixel electrode. The switching elements, the pixel electrode, and the counter electrode are provided on an insulating substrate.

One of the pixel electrode and the counter electrode is formed as a slit electrode having a slit portion and the other of the pixel electrode and the counter electrode is stacked over the slit electrode at the insulating substrate side with respect to the slit electrode with an insulating film interposed therebetween.

The array substrate includes a biaxial phase difference film and an array substrate polarizing plate arranged in this order on a surface of the insulating substrate opposite a side thereof facing the liquid crystal layer.

The counter substrate includes a counter substrate polarizing plate arranged on a side of the counter substrate opposite a side thereof facing the liquid crystal layer.

The slit portion of the slit electrode extends in a direction forming an angle exceeding 0° and not exceeding 15° relative to a horizontal direction of the liquid crystal panel in use.

A pretilt angle of a liquid crystal molecule forming the liquid crystal layer on the side of the array substrate is formed such that the liquid crystal molecule goes away from the array substrate in a direction to the left when viewed from a position facing a display surface of the liquid crystal panel. The direction to the left defines the horizontal direction. The pretilt angle of the liquid crystal molecule on the side of the counter substrate is formed such that the liquid crystal molecule goes away from the counter substrate in a direction to the right when viewed from a position facing the display surface of the liquid crystal panel. The direction to the right defines the horizontal direction.

One of a direction of a delay phase axis of the biaxial phase difference film and a direction of an absorption axis of the array substrate polarizing plate is arranged in a position rotated anticlockwise in an angular range from over 0° to 1° from the horizontal direction. Alternatively, one of a direction of an absorption axis of the counter substrate polarizing plate and an alignment direction of the liquid crystal molecule is arranged in a position rotated clockwise in an angular range from over 0° to 1° from the horizontal direction.

The liquid crystal panel of the present invention is capable of achieving excellent visibility of the liquid crystal panel when the display surface of the liquid crystal panel is viewed from above. Further, degradation of visibility can be suppressed that is to occur in the presence of manufacturing variations in any of the delay phase axis of the biaxial phase difference film, the respective absorption axes of the array substrate polarizing plate and the counter substrate polarizing plate, and the alignment direction of the liquid crystal molecule. As a result, the resultant liquid crystal panel is capable of achieving preferable viewing angle characteristics when the liquid crystal panel is viewed from a driver's seat or a front passenger's seat of a vehicle even in the presence of manufacturing variations.

A liquid crystal panel of the present invention includes an array substrate, a counter substrate arranged to face the array substrate, and a liquid crystal layer interposed between the array substrate and the counter substrate. The array substrate includes multiple switching elements arranged in a matrix, a pixel electrode connected to the switching elements, and a counter electrode capable of forming a fringe electric field between the counter electrode and the pixel electrode. The switching elements, the pixel electrode, and the counter electrode are provided on an insulating substrate.

One of the pixel electrode and the counter electrode is formed as a slit electrode having a slit portion and the other of the pixel electrode and the counter electrode is stacked over the slit electrode at the insulating substrate side with respect to the slit electrode with an insulating film interposed therebetween.

The array substrate includes a biaxial phase difference film and an array substrate polarizing plate arranged in this order on a surface of the insulating substrate opposite a side thereof facing the liquid crystal layer.

The counter substrate includes a counter substrate polarizing plate arranged on a side of the counter substrate opposite a side thereof facing the liquid crystal layer.

The slit portion of the slit electrode extends in a direction forming an angle exceeding 0° and not exceeding 15° relative to a horizontal direction of the liquid crystal panel in use.

A pretilt angle of a liquid crystal molecule forming the liquid crystal layer on the side of the array substrate is formed such that the liquid crystal molecule goes away from the array substrate in a direction to the right when viewed from a position facing a display surface of the liquid crystal panel. The direction to the right defines the horizontal direction. The pretilt angle of the liquid crystal molecule on the side of the counter substrate is formed such that the liquid crystal molecule goes away from the counter substrate in a direction to the left when viewed from a position facing the display surface of the liquid crystal panel. The direction to the left defines the horizontal direction.

One of a direction of a delay phase axis of the biaxial phase difference film and a direction of an absorption axis of the array substrate polarizing plate is arranged in a position rotated clockwise in an angular range from over 0° to 1° from the horizontal direction. Alternatively, one of a direction of an absorption axis of the counter substrate polarizing plate and an alignment direction of the liquid crystal molecule is arranged in a position rotated anticlockwise in an angular range from over 0° to 1° from the horizontal direction.

The liquid crystal panel of the present invention is capable of achieving excellent visibility of the liquid crystal panel when the display surface of the liquid crystal panel is viewed from above. Further, degradation of visibility can be suppressed that is to occur in the presence of manufacturing variations in any of the delay phase axis of the biaxial phase difference film, the respective absorption axes of the array substrate polarizing plate and the counter substrate polarizing plate, and the alignment direction of the liquid crystal molecule. As a result, the resultant liquid crystal panel is capable of achieving preferable viewing angle characteristics when the liquid crystal panel is viewed from a driver's seat or a front passenger's seat of a vehicle even in the presence of manufacturing variations.

A liquid crystal display device of the present invention includes the liquid crystal panel and an illumination unit to illuminate the liquid crystal panel.

The liquid crystal display device of the present invention is capable of achieving preferable viewing angle characteristics when the liquid crystal display device is viewed from a driver's seat or a front passenger's seat of a vehicle even in the presence of manufacturing variations in the liquid crystal panel.

A method of manufacturing a liquid crystal panel of the present invention is to manufacture a liquid crystal panel including an array substrate, a counter substrate arranged to face the array substrate, and a liquid crystal layer interposed between the array substrate and the counter substrate. The array substrate includes multiple switching elements arranged in a matrix, a pixel electrode connected to the switching elements, and a counter electrode capable of forming a fringe electric field between the counter electrode and the pixel electrode. The switching elements, the pixel electrode, and the counter electrode are provided on an insulating substrate.

The method includes the following steps.

A step of forming one of the pixel electrode and the counter electrode as a slit electrode having a slit portion and stacking the other of the pixel electrode and the counter electrode over the slit electrode at the insulating substrate side with respect to the slit electrode interposing an insulating film therebetween.

A step of providing a biaxial phase difference film and an array substrate polarizing plate in this order on a surface of the insulating substrate of the array substrate opposite a side thereof facing the liquid crystal layer.

A step of providing a counter substrate polarizing plate on a side of the counter substrate opposite a side thereof facing the liquid crystal layer.

A step of forming the slit electrode such that the slit portion extends in a direction forming an angle exceeding 0° and not exceeding 15° relative to a horizontal direction of the liquid crystal panel in use.

A step of setting a pretilt angle of a liquid crystal molecule forming the liquid crystal layer on the side of the array substrate such that the liquid crystal molecule goes away from the array substrate in a direction to the left when viewed from a position facing a display surface of the liquid crystal panel, the direction to the left defining the horizontal direction, and setting the pretilt angle of the liquid crystal molecule on the side of the counter substrate such that the liquid crystal molecule goes away from the counter substrate in a direction to the right when viewed from a position facing the display surface of the liquid crystal panel, the direction to the right defining the horizontal direction.

A step of arranging one of a direction of a delay phase axis of the biaxial phase difference film and a direction of an absorption axis of the array substrate polarizing plate in a position rotated anticlockwise in an angular range from over 0° to 1° from the horizontal direction or arranging one of a direction of an absorption axis of the counter substrate polarizing plate and an alignment direction of the liquid crystal molecule in a position rotated clockwise in an angular range from over 0° to 1° from the horizontal direction.

The method of manufacturing a liquid crystal panel of the present invention provides a liquid crystal panel capable of achieving preferable viewing angle characteristics when the liquid crystal panel is viewed from a driver's seat or a front passenger's seat of a vehicle even in the presence of manufacturing variations.

A method of manufacturing a liquid crystal panel of the present invention is to manufacture a liquid crystal panel including an array substrate, a counter substrate arranged to face the array substrate, and a liquid crystal layer interposed between the array substrate and the counter substrate. The array substrate includes multiple switching elements arranged in a matrix, a pixel electrode connected to the switching elements, and a counter electrode capable of forming a fringe electric field between the counter electrode and the pixel electrode. The switching elements, the pixel electrode, and the counter electrode are provided on an insulating substrate.

The method includes the following steps.

A step of forming one of the pixel electrode and the counter electrode as a slit electrode having a slit portion and stacking the other of the pixel electrode and the counter electrode over the slit electrode at the insulating substrate side with respect to the slit electrode interposing an insulating film therebetween.

A step of providing a biaxial phase difference film and an array substrate polarizing plate in this order on a surface of the insulating substrate of the array substrate opposite a side thereof facing the liquid crystal layer.

A step of providing a counter substrate polarizing plate on a side of the counter substrate opposite a side thereof facing the liquid crystal layer.

A step of forming the slit electrode such that the slit portion extends in a direction forming an angle exceeding 0° and not exceeding 15° relative to a horizontal direction of the liquid crystal panel in use.

A step of setting a pretilt angle of a liquid crystal molecule forming the liquid crystal layer on the side of the array substrate such that the liquid crystal molecule goes away from the array substrate in a direction to the right when viewed from a position facing a display surface of the liquid crystal panel, the direction to the right defining the horizontal direction, and setting the pretilt angle of the liquid crystal molecule on the side of the counter substrate such that the liquid crystal molecule goes away from the counter substrate in a direction to the left when viewed from a position facing the display surface of the liquid crystal panel, the direction to the left defining the horizontal direction.

A step of arranging one of a direction of a delay phase axis of the biaxial phase difference film and a direction of an absorption axis of the array substrate polarizing plate in a position rotated clockwise in an angular range from over 0° to 1° from the horizontal direction or arranging one of a direction of an absorption axis of the counter substrate polarizing plate and an alignment direction of the liquid crystal molecule in a position rotated anticlockwise in an angular range from over 0° to 1° from the horizontal direction.

The method of manufacturing a liquid crystal panel of the present invention provides a liquid crystal panel capable of achieving preferable viewing angle characteristics when the liquid crystal panel is viewed from a driver's seat or a front passenger's seat of a vehicle even in the presence of manufacturing variations.

These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view showing the structure of a liquid crystal panel **1** provided in a liquid crystal display device according to a first preferred embodiment of the present invention;

FIG. **2** is a sectional view of the liquid crystal panel **1** as viewed from a cutting plane line II-II of FIG. **1**;

FIG. **3** shows an example of arrangement of optical components of a liquid crystal panel according to a prerequisite technique;

FIG. **4** is a plan view showing an example of the position of an array substrate **10** and that of a liquid crystal molecule **41** relative to each other in the first preferred embodiment of the present invention;

FIG. **5** shows an example of arrangement of optical components of the liquid crystal panel **1** according to the first preferred embodiment of the present invention;

FIG. **6** explains a polar angle θ**3**;

FIG. **7** is a graph showing a relationship between an angle θ**2** of a delay phase axis **53** of a biaxial phase difference film **32***c* to a direction X and a contrast value determined in a direction of the polar angle θ**3** at an azimuth of 90°;

FIG. **8** shows an example of arrangement of optical components of a liquid crystal panel according to a second preferred embodiment of the present invention;

FIG. **9** is a graph showing a relationship between an angle θ**4** of an alignment axis **52** of the liquid crystal molecule **41** to the direction X and a contrast value determined in a direction of the polar angle θ**3** at an azimuth of 90°;

FIG. **10** shows an example of arrangement of optical components of a liquid crystal panel according to a third preferred embodiment of the present invention; and

FIG. **11** is a graph showing a relationship between an angle θ**5** of an absorption axis **51** of a counter substrate polarizing plate **32***a* to the direction X and a contrast value determined in a direction of the polar angle θ**3** at an azimuth of 90°.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Preferred Embodiment

FIG. **1** is a plan view showing the structure of a liquid crystal panel **1** provided in a liquid crystal display device according to a first preferred embodiment of the present invention. FIG. **2** is a sectional view of the liquid crystal panel **1** as viewed from a cutting plane line II-II of FIG. **1**.

The liquid crystal panel **1** shown as an example in FIGS. **1** and **2** adopts an in-plane system operated by using a thin film transistor (abbreviated as TFT) as a switching element. The liquid crystal panel **1** is more specifically a liquid crystal panel adopting a fringe field switching (FFS) system.

As shown in FIGS. **1** and **2**, the liquid crystal panel **1** includes a TFT array substrate (simply called an "array substrate" in some cases) **10**, a color filter substrate **20**, and a seal material **30**.

Both the array substrate **10** and the color filter substrate **20** are quadrilateral, more specifically rectangular in outer shape. In the first preferred embodiment, the outer shape of the array substrate **10** is larger than that of the color filter substrate **20**. The array substrate **10** has a protrusion protruding from an end surface of the outer circumference of the color filter substrate **20**. The array substrate **10** is superposed over the color filter substrate **20**. The array substrate **10** and the color filter substrate **20** are superposed such that one of the short sides of the array substrate **10** and that of the color filter substrate **20** are aligned with each other, one of the long sides of the array substrate **10** and that of the color filter substrate **20** are aligned with each other, and one of the corners of the array substrate **10** and that of the color filter substrate **20** are aligned with each other.

In the below, a direction of the long sides of the array substrate **10** and that of the long sides of the color filter substrate **20** are called a direction X. A direction of the short sides of the array substrate **10** and that of the short sides of the color filter substrate **20** are called a direction Y. The directions X and Y are perpendicular to each other. In FIG. **1**, the direction X includes a direction to the right and a direction to the left in the plane of the sheet. The direction Y includes an upward direction and a downward direction in the plane of the sheet.

One of the directions defining the direction X is called a direction X**1** and the other direction is called a direction X**2**. One of the directions defining the direction Y is called a direction Y**1** and the other direction is called a direction Y**2**. The direction X**1** mentioned herein is a direction from the right toward the left in the plane of the sheet of FIG. **1**. The direction X**2** mentioned herein is a direction from the left toward the right in the plane of the sheet of FIG. **1**. The direction Y**1** mentioned herein is an upward direction in the plane of the sheet of FIG. **1**. The direction Y**2** mentioned herein is a downward direction in the plane of the sheet of FIG. **1**. In terms of the time on a clock, each direction of FIG. **1** is expressed as follows: the direction X**1** is at the 9 o'clock position, the direction X**2** is at the 3 o'clock position, the direction Y**1** is at the 0 o'clock position, and the direction Y**2** is at the 6 o'clock position.

The array substrate **10** includes TFTs **14** as switching elements arranged in a matrix. The color filter substrate **20** is a counter substrate aligned so as to face the array substrate **10**. The color filter substrate **20** has a display region S**2** where images are to be displayed. The seal material **30** is arranged so as to surround a region corresponding to the display region S**2**. The seal material **30** hermetically closes a gap between the color filter substrate **20** and the array substrate **10**.

A large number of columnar spacers not shown in the drawings are arranged in the display region S**2** between the array substrate **10** and the color filter substrate **20**. The columnar spacers form and maintain the gap of a constant distance between the array substrate **10** and the color filter substrate **20**.

The gap between the color filter substrate **20** and the array substrate **10** hermetically closed by the seal material **30** and maintained by the columnar spacers includes a region which corresponds at least to the display region S**2** and in which a liquid crystal layer **40** is interposed. The seal material **30** is arranged in a frame region S**1** external to the region corresponding to the display region S**2**.

The "display region S**2**" mentioned herein is a region to be used for display extending over the array substrate **10**, extending over the color filter substrate **20**, or interposed between the array substrate **10** and the color filter substrate **20** of the liquid crystal panel **1**.

The "frame region S**1**" is a region of a configuration like a frame external to the display region S**2** and surrounding the display region S**2**. The frame region S**1** extends over the array substrate **10**, extends over the color filter substrate **20**, or is interposed between the substrates **10** and **20** of the liquid crystal panel **1**. In the first preferred embodiment, the frame region S**1** is a residual region determined by subtracting the display region S**2** from the entire region over the array substrate **10**, over the color filter substrate **20**, or interposed between the substrates **10** and **20** of the liquid crystal panel **1**.

The color filter substrate **20** includes a glass substrate **21** as a first transparent substrate, an alignment film **22***b* for alignment of a liquid crystal, color filters **24** in a colorant layer, a light shielding layer **25**, and an overcoat layer **26**.

The alignment film **22***b* is provided in a region corresponding to the display region S**2** and extending over one of surfaces of the glass substrate **21** in the thickness direction thereof. The color filters **24**, the light shielding layer **25**, and the overcoat layer **26** are provided between the alignment film **22***b* and the glass substrate **21**. The light shielding layer

25 is provided to shield space between the color filters 24 from light or to shield the frame region S1 arranged externally to a region corresponding to the display region S2 from light. The overcoat layer 26 is provided so as to cover the color filters 24 and the light shielding layer 25.

The color filters 24 are formed of colorant layers containing a pigment dispersed in resin, for example. The color filters 24 function as filters to selectively let light pass through that may be red, green, or blue light in a particular wavelength range. The color filters 24 are formed of the colorant layers of these colors arranged regularly.

The light shielding layer 25 is made of a metallic material using chrome oxide or the like or a resin-based material containing black particles dispersed in resin, for example. In the first preferred embodiment, as shown in FIG. 2, the overcoat layer 26 formed of a transparent resin film is provided at a shorter distance to the glass substrate 21 than the alignment film 22*b*. The overcoat layer 26 is provided so as to cover and flatten the color filters 24 and the light shielding layer 25.

The color filter substrate 20 includes an antistatic transparent conductive layer 31 provided on the other of the surfaces of the glass substrate 21 in the thickness direction thereof. The antistatic transparent conductive layer 31 is ground-connected. The antistatic transparent conductive layer 31 is provided so as to cover the glass substrate 21 at least in the display region S2. In the liquid crystal panel 1 of an in-plane system of the first preferred embodiment, the antistatic transparent conductive layer 31 is provided to effectively prevent a display failure due to an electrostatically charged state and application of an external electric field.

The array substrate 10 includes a glass substrate 11 as a second transparent substrate, an alignment film 22*a* for alignment of a liquid crystal, a pixel electrode 12, a counter electrode 13, the TFTs 14, an insulating film 15, multiple gate lines 16 and multiple source lines 17, and gate electrodes, source electrodes, and drain electrodes not shown in the drawings.

The alignment film 22*a* is provided on a surface of the glass substrate 11 facing the color filter substrate 20 and in a region corresponding to the display region S2. The pixel electrode 12 and the counter electrode 13 are each provided at a shorter distance to the glass substrate 11 than the alignment film 22*a*. The pixel electrode 12 and the counter electrode 13 form an electrode pair to generate an electric field in a direction parallel to a substrate surface of the array substrate 10 or the color filter substrate 20, thereby generating a voltage to drive a liquid crystal.

The TFTs 14 are switching elements to write a voltage to the pixel electrode 12 as one of the electrode pair. The TFTs 14 are connected to the pixel electrode 12 and apply a voltage to the pixel electrode 12. The TFTs 14 are covered with the insulating film 15.

The gate lines 16 and the source lines 17 are to supply signals to the TFTs 14. The gate lines 16 are connected to the gate electrodes of the TFTs 14. The source lines 17 are connected to the source electrodes or gate electrodes of the TFTs 14.

In the first preferred embodiment, the pixel electrode 12 and the counter electrode 13 forming the electrode pair to apply a voltage to drive a liquid crystal are configured as follows. The pixel electrode 12 as one of the electrode pair is formed of a transparent conductive film pattern of a flat plate configuration. The counter electrode 13 as the other of the electrode pair is formed of a transparent conductive film pattern of a comb-like configuration or a transparent conductive film pattern with multiple opening portions like slits arranged in parallel. The counter electrode 13 is superposed over the pixel electrode 12 while an insulating layer is held between the counter electrode 13 and the pixel electrode 12.

In the below, an electrode like the counter electrode 13 formed of a transparent conductive film pattern of a comb-like configuration or a transparent conductive film pattern with multiple opening portions like slits arranged in parallel is called a “slit electrode” in some cases. An electrode portion of the transparent conductive film pattern of a comb-like configuration and the multiple opening portions like slits of the transparent conductive film pattern with these opening portions like slits are called a “slit portion” in some cases.

The respective configurations of the pixel electrode 12 and the counter electrode 13 are not limited to those described above. As an example, the respective configurations of the pixel electrode 12 and the counter electrode 13 and the arrangement of the pixel electrode 12 and the counter electrode 13 in terms of their positions in a vertical direction may be reversed from those of the first preferred embodiment.

In this case, the pixel electrode 12 is formed as a slit electrode. More specifically, the pixel electrode 12 is formed of a transparent conductive film pattern of a comb-like configuration or a transparent conductive film pattern with multiple opening portions like slits arranged in parallel. The pixel electrode 12 is placed in a higher position than the counter electrode 13. The counter electrode 13 is formed of a transparent conductive film pattern of a flat plate configuration and is placed in a lower position than the pixel electrode 12.

A specific planar pattern configuration of the pixel electrode 12 and that of the counter electrode 13 are not shown in the drawings and will not be described. The pixel electrode 12 and the counter electrode 13 may have respective planar pattern configurations of a pixel electrode and a counter electrode used in a liquid crystal panel adopting a publicly-known FFS system.

An insulating film of the first preferred embodiment including the insulating film 15 forming the array substrate 10 and the insulating film not shown in the drawings formed between the pixel electrode 12 and the counter electrode 13 is formed of a single-layer transparent insulating film or a stacked film with transparent insulating films stacked in multiple layers.

As shown in outline in FIG. 1, the multiple gate lines 16 formed in the display region S2 are arranged parallel to each other. Likewise, the multiple source lines 17 are arranged parallel to each other in the display region S2. The gate lines 16 and the source lines 17 cross each other.

The pixel electrodes 12 and the TFTs 14 are arranged in a matrix in a corresponding relationship with regions each surrounded by the gate lines 16 and the source lines 17 crossing each other (hereinafter called a “pixel region” in some cases). In the first preferred embodiment, one pixel electrode 12 and one TFT 14 are provided in one pixel region.

Common lines 13L through which a common potential is to be supplied to the counter electrode 13 extend parallel to the gate lines 16. The number of the common lines 13L is the same as that of the gate lines 16. Each common line 13L is connected to the counter electrode 13 in a corresponding pixel region and standardizes each potential of the counter electrode 13 in each pixel region at a common potential.

A signal terminal 18 is provided in the frame region S1 over the array substrate 10 and on a surface of the protrusion protruding from the end surface of the outer circumference of the color filter substrate **20**. This surface of the protrusion belongs to a side where the color filter substrate **20** is arranged. The signal terminal **18** receives a signal to be supplied to the TFT **14** from outside and applies the received signal to the TFT **14**.

The signal terminal **18** is shown as an integrated configuration in FIGS. **1** and **2**. The signal terminal **18** is actually configured as follows. Quadrilateral pads each having a longitudinal side extending in a direction perpendicular to a neighboring substrate end side are formed to be spaced from each other so as to be responsive to multiple signals. A large number of signal terminals **18** are arranged in the direction of the short side of each pad.

Each pad of the signal terminal **18** is connected to a control substrate **35** through a flexible flat cable (abbreviated as FFC) **36** functioning as a connection line. The control substrate **35** includes a control integrated circuit (IC) chip to generate a control signal or the like to control a driver IC, for example.

The control signal from the control substrate **35** is input through the signal terminal **18** to an input side of a driver IC chip **34** attached to the protrusion. An output signal to be output from an output side of the driver IC chip **34** is supplied to the TFTs **14** in the display region S**2** through a large number of signal leading lines pulled out from the display region S**2**.

The color filter substrate **20** as the counter substrate includes a counter substrate polarizing plate **32***a* provided in a layer on the antistatic transparent conductive layer **31** provided on an external surface relative to the liquid crystal layer **40**.

The array substrate **10** includes an array substrate polarizing plate **32***b* and a biaxial phase difference film **32***c* provided on a surface of the glass substrate **11** opposite a side thereof facing the liquid crystal layer **40**, specifically on an external surface of the glass substrate **11**. The biaxial phase difference film **32***c* is provided on the surface of the glass substrate **11** opposite the side thereof facing the liquid crystal layer **40**, specifically on the external surface of the glass substrate **11**. The array substrate polarizing plate **32***b* is arranged external to the biaxial phase difference film **32***c* and stacked on the biaxial phase difference film **32***c*. Specifically, the biaxial phase difference film **32***c* and the array substrate polarizing plate **32***b* are stacked in this order on the glass substrate **11**.

The counter substrate polarizing plate **32***a*, the array substrate polarizing plate **32***b*, and the biaxial phase difference film **32***c* are provided so as to cover at least the display region S**2** of the color filter substrate **20** and the array substrate **10**.

A particular optical design, a method of setting an optical axis, and a manufacturing method about each of the counter substrate polarizing plate **32***a*, the array substrate polarizing plate **32***b*, and the biaxial phase difference film **32***c* are described later.

The antistatic transparent conductive film **31** formed on the surface of the color filter substrate **20** is ground-connected. As an example, in the first preferred embodiment, an earth pad not shown in the drawings is provided to the protrusion of the array substrate **10**. The antistatic transparent conductive layer **31** and the earth pad are connected through a conductive tape not shown in the drawings. This connects the antistatic transparent conductive layer **31** to the ground.

The antistatic transparent conductive layer **31** is mostly covered with the counter substrate polarizing plate **32***a*. The antistatic transparent conductive layer **31** has an exposed part not covered with the counter substrate polarizing plate **32***a* to be partially exposed at an end portion of the color filter substrate **20**. The conductive tape is connected to the antistatic transparent conductive layer **31** by being attached to the exposed part of the antistatic transparent conductive layer **31**.

The liquid crystal display device of the first preferred embodiment includes the liquid crystal panel **1** of the aforementioned structure, a backlight unit not shown in the drawings, an optical sheet not shown in the drawings, and a case not shown in the drawings. The backlight unit corresponds to an illumination unit.

The backlight unit is arranged on a side opposite a display surface formed in the display region S**2** of the color filter substrate **20** while the optical sheet is placed between the liquid crystal panel **1** and the backlight unit. The backlight unit faces the substrate surface of the array substrate **10** to function as a light source. The optical sheet has the function of adjusting light from the backlight unit (hereinafter called "backlighting light" in some cases).

The case has a configuration with a portion through which the display surface of the display region S**2** is opened. The liquid crystal display device includes the liquid crystal panel **1** and optical components including the aforementioned backlight unit and optical sheet accommodated together in the case.

The following describes a particular structure, more specifically an optical design and advantageous effects achieved by the design relating to each of the counter substrate polarizing plate **32***a*, the array substrate polarizing plate **32***b*, and the biaxial phase difference film **32***c*. A prerequisite technique is explained first.

FIG. **3** shows an example of arrangement of optical components of a liquid crystal panel according to the prerequisite technique. The optical components shown in FIG. **3** include the counter substrate polarizing plate **32***a*, the array substrate polarizing plate **32***b*, and the biaxial phase difference film **32***c*.

The counter substrate polarizing plate **32***a* is arranged such that an absorption axis **51** forms an angle of 0° relative to the direction X, specifically such that the absorption axis **51** becomes parallel to the direction X**1**. The array substrate polarizing plate **32***b* is arranged such that an absorption axis **54** forms an angle of 90° relative to the direction X, specifically such that the absorption axis **54** becomes perpendicular to the direction X.

Backlighting light enters from a direction of an arrow **50** that is a direction perpendicular to the external surface of the array substrate polarizing plate **32***b*. Specifically, the incident direction **50** of backlighting light is perpendicular to the directions X and Y.

An alignment direction of a liquid crystal molecule **41** corresponds to a direction of an alignment axis **52** of the liquid crystal molecule **41**. In the first preferred embodiment, the alignment direction of the liquid crystal molecule **41** is set at an angle of 0° relative to the direction X, specifically set to be parallel to the direction X. A pretilt angle θ**1** of the liquid crystal molecule **41** on the side of the array substrate **10** is set such that the liquid crystal molecule **41** goes away from the array substrate **10** in the direction X**1** at the 9 o'clock position. The pretilt angle θ**1** of the liquid crystal molecule **41** on the side of the counter substrate **20** is set such that the liquid crystal molecule **41** goes away from the counter substrate **20** in the direction X**2** at the 3 o'clock position.

The "alignment direction" mentioned herein is a direction of alignment process such as rubbing performed on the alignment films **22***a* and **22***b*. The "pretilt angle" mentioned herein is an angle a long axis **42** of each liquid crystal molecule **41** forms relative to a surface of the array substrate **10** or the counter substrate **20** facing the liquid crystal layer **40** if no voltage is applied to the liquid crystal layer **40**.

In the liquid crystal panel having the pretilt angle set in the aforementioned way, the biaxial phase difference film **32***c* is used for enhancing viewing angle characteristics. According to the prerequisite technique, the biaxial phase difference film **32***c* is arranged so as to achieve maximum contrast if the liquid crystal panel is viewed from the front while a viewing direction of the liquid crystal panel has no particular directivity.

More specifically, as shown in FIG. **3**, the biaxial phase difference film **32***c* is arranged such that a delay phase axis **53** of the biaxial phase difference film **32***c* extends in a direction parallel to the alignment direction of the liquid crystal molecule **41**, specifically in a direction at an angle of 0° relative to the direction X in a plan view taken from a direction perpendicular to a substrate surface of the liquid crystal panel and opposite the incident direction **50** of backlighting light.

In contrast, in the first preferred embodiment, the biaxial phase difference film **32***c* is arranged such that the delay phase axis **53** of the biaxial phase difference film **32***c* extends in a direction that achieves maximum contrast if the liquid crystal panel is viewed from a position shifted from the front. More specifically, the biaxial phase difference film **32***c* is arranged as shown in FIGS. **4** and **5**.

FIG. **4** is a plan view showing an example of the position of the array substrate **10** and that of the liquid crystal molecule **41** relative to each other in the first preferred embodiment of the present invention. FIG. **5** shows an example of arrangement of the optical components of the liquid crystal panel **1** according to the first preferred embodiment of the present invention.

In the first preferred embodiment, the counter electrode **13** as the slit electrode of the array substrate **10** is formed such that the slit portion of the slit electrode extends in a direction forming an angle exceeding 0° and not exceeding 15° relative to the direction X corresponding to the horizontal direction of the liquid crystal panel **1**. More specifically, the counter electrode **13** is arranged such that its slit portion becomes vertically symmetric about the center of the pixel electrode **12** as an axis of symmetry.

The liquid crystal molecule **41** is aligned in a direction parallel to a direction **60** at an angle of 0° corresponding to the horizontal direction of the liquid crystal panel **1**. Like the liquid crystal panel of the prerequisite technique, the liquid crystal panel **1** of the first preferred embodiment is a liquid crystal panel of an FFS mode adopting an optical compensating method using the biaxial phase difference film **32***c*.

Thus, like in the aforementioned case described by referring to FIG. **3**, the pretilt angle θ**1** of the liquid crystal molecule **41** on the side of the array substrate **10** is set such that the liquid crystal molecule **41** goes away from the array substrate **10** in the direction X1 at the 9 o'clock position. The pretilt angle θ**1** of the liquid crystal molecule **41** on the side of the counter substrate **20** is set such that the liquid crystal molecule **41** goes away from the counter substrate **20** in the direction X2 at the 3 o'clock position.

In the liquid crystal panel **1** having the pretilt angle set in the aforementioned way, according to the first preferred embodiment, a certain shift angle θ**2** is set such that the direction of the delay phase axis **53** of the biaxial phase difference film **32***c* is shifted anticlockwise in an angular range from over 0° to 1° from the direction X corresponding to the direction of 0° as shown in FIG. **5**. Specifically, the direction of the delay phase axis **53** of the biaxial phase difference film **32***c* is arranged in a position rotated anticlockwise in the angular range from over 0° to 1° from the direction X corresponding to the horizontal direction of the liquid crystal panel **1** in use.

The "shift angle θ**2**" mentioned herein is an angle of shift of the delay phase axis **53** of the biaxial phase difference film **32***c* from the direction X and showing an angle between the delay phase axis **53** of the biaxial phase difference film **32***c* and the direction X.

The absorption axes **51** and **54** of the polarizing plates **32***a* and **32***b* respectively are set in the same way as in the aforementioned prerequisite technique described by referring to FIG. **3**. More specifically, the absorption axis **51** of the counter substrate polarizing plate **32***a* is arranged in a direction of an angle of 0°, specifically in a direction parallel to the direction X corresponding to the alignment direction of the liquid crystal molecule **41** in a plan view. The absorption axis **54** of the array substrate polarizing plate **32***b* is arranged in a direction of an angle of 90°, specifically in a direction perpendicular to the direction X corresponding to the alignment direction of the liquid crystal molecule **41** in a plan view.

In the first preferred embodiment, the biaxial phase difference film **32***c* and the polarizing plates **32***a* and **32***b* are arranged such that the respective end sides of the outer shapes thereof as they are become parallel to respective end surfaces of the glass substrates **11** and **21** forming the array substrate **10** and the counter substrate **20** respectively. Specifically, in the first preferred embodiment, only the direction of the delay phase axis **53** of the biaxial phase difference film **32***c* is shifted from the respective end sides of the outer shapes of the biaxial phase difference film **32***c* and the polarizing plates **32***a* and **32***b*.

Thus, while the polarizing plates **32***a* and **32***b* and the biaxial phase difference film **32***c* are bonded at respective angles same as those in the prerequisite technique and the respective end sides of the outer shapes of the biaxial phase difference film **32***c* and the polarizing plates **32***a* and **32***b* are parallel to the respective end surfaces of the glass substrates **11** and **21**, the delay phase axis **53** of the biaxial phase difference film **32***c* can be set at an angle tilted from the direction X corresponding to the direction of the alignment axis **52** of the liquid crystal molecule **41**.

Unlike in the first preferred embodiment, if the pretilt angle θ**1** is set in a way opposite to the way shown in FIG. **5**, the orientation of the delay phase axis **53** of the biaxial phase difference film **32***c* is also set in a way opposite to the way shown in FIG. **5**. More specifically, in this case, the pretilt angle θ**1** of the liquid crystal molecule **41** on the side of the array substrate **10** is set such that the liquid crystal molecule **41** goes away from the array substrate **10** in the direction X2 at the 3 o'clock position. The pretilt angle θ**1** of the liquid crystal molecule **41** on the side of the counter substrate **20** is set such that the liquid crystal molecule **41** goes away from the counter substrate **20** in the direction X1 at the 9 o'clock position.

In a liquid crystal panel having this pretilt angle, the certain shift angle θ**2** is set in a way opposite to the way shown in FIG. **5** such that the direction of the delay phase axis **53** of the biaxial phase difference film **32***c* is shifted clockwise in an angular range from over 0° to 1° from the direction X corresponding to the direction of 0°. Specifically, the direction of the delay phase axis **53** of the biaxial phase difference film **32***c* is arranged in a position rotated clockwise in the angular range from over 0° to 1° from the direction X.

According to the aforementioned optical design of the prerequisite technique such as that shown in FIG. **3**, contrast becomes highest when the liquid crystal panel is viewed from the front, specifically viewed in a direction perpendicular to the front of the liquid crystal panel or to the display surface of the liquid crystal panel and a direction near the perpendicular direction. Contrast obtained in the direction Y including the upward and downward directions becomes symmetric relative to a center line.

In contrast, according to the first preferred embodiment, the certain shift angle θ**2** is set such that the direction of the delay phase axis **53** of the biaxial phase difference film **32***c* is shifted anticlockwise in an angular range from over 0° to 1° from the direction X corresponding to the direction of 0° as shown in FIG. **5**. This optical design allows the liquid crystal panel **1** to achieve the highest contrast when the liquid crystal panel **1** is viewed from above relative to the display surface, specifically viewed in the direction Y**1**.

FIG. **6** explains a polar angle θ**3**. FIG. **7** is a graph showing a relationship between the angle θ**2** of the delay phase axis **53** of the biaxial phase difference film **32***c* to the direction X and a contrast value determined in a direction of the polar angle θ**3** at an azimuth of 90°. The horizontal axis of FIG. **7** shows the angle θ**2**(°) between the delay phase axis **53** and the direction X. The vertical axis of FIG. **7** shows contrast (relative value). FIG. **7** shows a result of calculation of a contrast value at a corresponding polar angle θ**3** obtained by changing the angle θ**2** between the delay phase axis **53** of the biaxial phase difference film **32***c* and the direction X. The contrast value was calculated using a simulator "LCD master" available from SHINTECH, Inc.

The polar angle θ**3** mentioned herein is an angle between a direction **61** perpendicular to the directions **Y1** and **Y2** corresponding to the upward and downward directions relative to the display surface of the liquid crystal panel **1**, specifically the direction **61** perpendicular to the display surface of the liquid crystal panel **1** and a viewing direction **62**. The azimuth mentioned herein is an angle relative to the direction X parallel to the display surface of the liquid crystal panel **1** and perpendicular to the directions **Y1** and **Y2**. The direction X is perpendicular to the plane of the sheet of FIG. **6**. Thus, a direction at the azimuth of 90° becomes parallel to the plane of the sheet of FIG. **6**, specifically parallel to the directions **Y1** and **Y2**.

FIG. **7** shows a calculation result indicated by a reference sign "**70**" obtained with the polar angle θ**3** of 0°, specifically obtained when the liquid crystal panel **1** is viewed from the front. FIG. **7** further shows a calculation result indicated by a reference sign "**71**" obtained with the polar angle θ**3** of 10°, a calculation result indicated by a reference sign "**72**" obtained with the polar angle θ**3** of 20°, and a calculation result indicated by a reference sign "**73**" obtained with the polar angle θ**3** of 30°.

Advantageous effects achieved by the structure of the first preferred embodiment are described by referring to FIG. **7**. The calculation results given in FIG. **7** show that setting the shift angle θ**2** of the delay phase axis **53** of the biaxial phase difference film **32***c* in an angular range from over 0° to 1° as in the first preferred embodiment makes it possible to finely adjust and optimize viewing angle characteristics so as to achieve maximum contrast in a range of the polar angle θ**3** from over 0° to 30° optimum for a liquid crystal display device to be installed on a vehicle.

The biaxial phase difference film **32***c* is biaxially stretched to generate a phase difference during a step of manufacturing the same. During the step, a bowing phenomenon may occur to cause a deviation of about ±1.0° from an intended angle in the delay phase axis **53** of the biaxial phase difference film **32***c*. The "bowing phenomenon" mentioned herein is a phenomenon where a film being manufactured by biaxial stretching process is deformed faster or slower in a central portion of the width direction of the film than in an end portion of the width direction.

According to the aforementioned optical design of the prerequisite technique shown in FIG. **3**, if the delay phase axis **53** of the biaxial phase difference film **32***c* is shifted toward a negative side, the polar angle θ**3** becomes negative, specifically contrast becomes maximum when a liquid crystal panel is viewed from below. This degrades the visibility of a liquid crystal display device to be installed on a vehicle.

In contrast, in the first preferred embodiment, the delay phase axis **53** of the biaxial phase difference film **32***c* is placed on a positive side in advance as shown in FIG. **5** referred to previously. This can prevent the shift angle θ**2** of the delay phase axis **53** from becoming a negative angle, even if the delay phase axis **53** of the biaxial phase difference film **32***c* is shifted toward a negative side due to manufacturing variations. This can prevent a situation where contrast becomes maximum when the liquid crystal panel **1** is viewed from below.

Second Preferred Embodiment

FIG. **8** shows an example of arrangement of optical components of a liquid crystal panel according to a second preferred embodiment of the present invention. The liquid crystal panel of the second preferred embodiment is similar to that of the first preferred embodiment. A structure same as that of the first preferred embodiment is identified by the same reference sign and description common to these structures will not be given repeatedly. In the second preferred embodiment, the direction of the slit portion of the slit electrode, the alignment direction of the liquid crystal molecule **41**, the directions of the absorption axes **51** and **54** of the polarizing plates **32***a* and **32** respectively, and the direction of the delay phase axis **53** of the biaxial phase difference film **32***c* are the same as those of the first preferred embodiment. Like in the first preferred embodiment, a slit electrode of the second preferred embodiment is the counter electrode **13**.

Like in the first preferred embodiment, the counter electrode **13** as the slit electrode of the array substrate **10** is formed so as to form an angle exceeding 0° and not exceeding 15° relative to the horizontal direction of the liquid crystal panel, specifically to the direction X including the directions to the right and to the left relative to the display surface of the liquid crystal panel as shown in FIG. **4** referred to previously. The liquid crystal molecule **41** is aligned in a direction parallel to the direction X corresponding to the horizontal direction of the liquid crystal panel.

Like in the first preferred embodiment, the liquid crystal panel of the second preferred embodiment is a liquid crystal panel of an FFS mode adopting an optical compensating method using the biaxial phase difference film **32***c*. Further, as shown in FIG. **3** referred to previously, the pretilt angle θ**1** is set such that the liquid crystal molecule **41** goes away from the array substrate **10** in the direction **X1** at the 9 o'clock position.

In the liquid crystal panel having the aforementioned pretilt angle, a certain shift angle θ**4** is set such that the alignment axis (hereinafter called a "liquid crystal alignment axis" in some cases) **52** of the liquid crystal molecule **41** is shifted clockwise in an angular range from over 0° to 1° from the direction X corresponding to the direction of 0° as shown in FIG. **8**. If the pretilt angle θ**1** rises in the opposite direction (hereinafter called a "pretilt direction" in some cases), the certain shift angle θ**4** is set such that the alignment axis **52** is shifted anticlockwise in an angular range from over 0° to 1° from the direction of 0°.

Alignment process such as rubbing is performed on an alignment film during manufacture while allowing for some variations of less than 1° for the liquid crystal alignment axis **52** to occur during the process. Thus, "setting the certain shift angle" mentioned herein means setting a median of design values. More specifically, an average is managed and set so as to fall within the aforementioned range of the certain shift angle in consideration of the variations to occur during the process.

Like that of the first preferred embodiment, the optical design of the second preferred embodiment such as that shown in FIG. **8** allows the liquid crystal panel to achieve the highest contrast when the liquid crystal panel is viewed from above as in the first preferred embodiment.

FIG. **9** is a graph showing a relationship between the angle θ**4** of the alignment axis **52** of the liquid crystal molecule **41** to the direction X and a contrast value determined in a direction of the polar angle θ**3** at the azimuth of 90°. The horizontal axis of FIG. **9** shows the shift angle θ**4**(°) corresponding to the angle between the alignment axis **52** of the liquid crystal molecule **41** and the direction X. The vertical axis of FIG. **9** shows contrast (relative value). FIG. **9** shows a result of calculation of a contrast value at a corresponding polar angle θ**3** obtained by changing the angle between the alignment axis **52** of the liquid crystal molecule **41** and the direction X. Like in the case of FIG. **7** referred to previously, the contrast value was calculated using a simulator "LCD master" available from SHINTECH, Inc.

FIG. **9** shows a calculation result indicated by a reference sign "**80**" obtained with the polar angle θ**3** of 0°, specifically obtained when the liquid crystal panel **1** is viewed from the front. FIG. **9** further shows a calculation result indicated by a reference sign "**81**" obtained with the polar angle θ**3** of 10°, a calculation result indicated by a reference sign "**82**" obtained with the polar angle θ**3** of 20°, and a calculation result indicated by a reference sign "**83**" obtained with the polar angle θ**3** of 30°.

The calculation results given in FIG. **9** show that by setting the shift angle θ**4** of the alignment axis **52** of the liquid crystal molecule **41** to be from 0° to −1° as viewed in the clockwise direction, specifically to be −1° or more and less than 0° as viewed in the anticlockwise direction as a positive direction as in the second preferred embodiment, viewing angle characteristics can be finely adjusted and optimized so as to achieve maximum contrast in a range of the polar angle θ**3** from over 0° to 30° optimum for a liquid crystal display device to be installed on a vehicle.

Third Preferred Embodiment

FIG. **10** shows an example of arrangement of optical components of a liquid crystal panel according to a third preferred embodiment of the present invention. The liquid crystal panel of the third preferred embodiment is similar to those of the first and second preferred embodiments. A structure same as that of the first and second preferred embodiments is identified by the same reference sign and description common to these structures will not be given repeatedly. In the third preferred embodiment, a direction of the slit portion of the slit electrode, the alignment direction of the liquid crystal molecule **41**, the direction of the absorption axis **54** of the array substrate polarizing plate **32***b*, and the direction of the delay phase axis **53** of the biaxial phase difference film **32***c* are the same as those of the first and second preferred embodiments. Like in the first preferred embodiment, a slit electrode of the third preferred embodiment is the counter electrode **13**.

Like in the first preferred embodiment, the counter electrode **13** as the slit electrode of the array substrate **10** is formed so as to form an angle exceeding 0° and not exceeding 15° relative to the horizontal direction of the liquid crystal panel, specifically to the direction X including the directions to the right and to the left relative to the display surface of the liquid crystal panel as shown in FIG. **4** referred to previously. The liquid crystal molecule **41** is aligned in a direction parallel to the direction X corresponding to the horizontal direction of the liquid crystal panel.

Like in the first preferred embodiment, the liquid crystal panel of the third preferred embodiment is a liquid crystal panel of an FFS mode adopting an optical compensating method using the biaxial phase difference film **32***c*. Further, as shown in FIG. **3** referred to previously, the pretilt angle θ**1** is set such that the liquid crystal molecule **41** goes away from the array substrate **10** in the direction X**1** at the 9 o'clock position.

In the liquid crystal panel having the aforementioned pretilt angle, a certain shift angle θ**5** is set such that the absorption axis **51** of the counter substrate polarizing plate **32***a* is shifted anticlockwise in an angular range from over 0° to 1° from the direction X corresponding to the direction of 0° as shown in FIG. **10**. If the pretilt direction is the opposite direction, the certain shift angle θ**5** is set such that the absorption axis **51** of the counter substrate polarizing plate **32***a* is shifted clockwise in an angular range from over 0° to 1° from the direction X corresponding to the direction of 0°.

In the third preferred embodiment, an end side of the outer shape of the counter substrate polarizing plate **32***a* is set such that this end side as it is becomes parallel to an end surface of the glass substrate **21** while only the absorption axis **51** of the counter substrate polarizing plate **32***a* is shifted from the end side of the outer shape of the counter substrate polarizing plate **32***a*. As a result, while the counter substrate polarizing plate **32***a* is bonded at an angle that makes the end side of the outer shape of the counter substrate polarizing plate **32***a* parallel to the end surface of the glass substrate **21** as in the prerequisite technique, the direction of the absorption axis **51** of the counter substrate polarizing plate **32***a* can be set at an angle tilted from the alignment direction of the liquid crystal molecule **41**.

Like those of the first and second preferred embodiments, the optical design of the third preferred embodiment such as that shown in FIG. **10** allows the liquid crystal panel to achieve the highest contrast when the liquid crystal panel is viewed from above.

FIG. **11** is a graph showing a relationship between the angle θ**5** of the absorption axis **51** of the counter substrate polarizing plate **32***a* to the direction X and a contrast value determined in a direction of the polar angle θ**3** at the azimuth of 90°. The horizontal axis of FIG. **11** shows the shift angle θ**5**(°) corresponding to the angle between the absorption axis **51** of the counter substrate polarizing plate **32***a* and the direction X. The vertical axis of FIG. **11** shows contrast (relative value). FIG. **11** shows a result of calculation of a contrast value at a corresponding polar angle θ3 obtained by changing the angle between the absorption axis **51** of the counter substrate polarizing plate **32***a* and the direction X. Like in the cases of FIGS. **7** and **9** referred to previously, the contrast value was calculated using a simulator "LCD master" available from SHINTECH, Inc.

FIG. **11** shows a calculation result indicated by a reference sign "**90**" obtained with the polar angle θ**3** of 0°, specifically obtained when the liquid crystal panel **1** is viewed from the front. FIG. **11** further shows a calculation result indicated by a reference sign "**91**" obtained with the polar angle θ**3** of 10°, a calculation result indicated by a reference sign "**92**" obtained with the polar angle θ**3** of 20°, and a calculation result indicated by a reference sign "**93**" obtained with the polar angle θ**3** of 30°.

The calculation results given in FIG. **11** show that setting the shift angle θ**5** of the absorption axis **51** of the counter substrate polarizing plate **32***a* in an angular range from over 0° to 1° as viewed in the anticlockwise direction as in the third preferred embodiment makes it possible to finely adjust and optimize viewing angle characteristics so as to achieve maximum contrast in a range of the polar angle θ**3** from over 0° to 30° optimum for a liquid crystal display device to be installed on a vehicle.

During manufacture of a liquid crystal display device including a polarizing plate or a biaxial phase difference film having an optical axis (delay phase axis or absorption axis) at a shifted angle of the first and third preferred embodiments, a liquid crystal panel having an optical axis set at a certain angle shifted from a liquid crystal cell can be obtained with better reproducibility as follows in consideration of variations in the angle of the optical axis to be caused during manufacture of the polarizing plate and the biaxial phase difference film.

More specifically, an end side of the outer shape of the biaxial phase difference film **32***c* like a quadrilateral sheet is given the aforementioned certain shift angle and the direction of the optical axis of the first preferred embodiment. In a step of bonding the polarizing plate and the biaxial phase difference film to the liquid crystal cell to form the liquid crystal panel, the polarizing plate and the biaxial phase difference film like quadrilateral sheets are aligned and bonded such that respective end sides of the outer shapes of the polarizing plate and the biaxial phase difference film become parallel as accurately as possible to an end side of the outer shape of a quadrilateral substrate of the liquid crystal cell. This can easily place the optical axis at a certain angle shifted from the liquid crystal cell.

The following describes an example of a particular method of preparing the polarizing plate and the biaxial phase difference film like quadrilateral sheets each having an optical axis given a certain shift angle and a direction, specifically an optical axis shifted in advance from the end side of the outer shape of a corresponding one of the polarizing plate and the biaxial phase difference film. In a step of cutting the respective outer shapes of the polarizing plate and the biaxial phase difference film, the polarizing plate and the biaxial phase difference film are each arranged at an angle satisfying a particular optical condition while optical measurement is made with a reference optical sheet having an optical axis in an accurately specified direction. As a result, the direction of the optical axis of each of the polarizing plate and the biaxial phase difference film before the cutting is specified accurately. Then, each the polarizing plate and the biaxial phase difference film member is cut such that the end side thereof is placed at the certain angle shifted from the specified direction of its optical axis. As a result, the polarizing plate and the biaxial phase difference film member each having an intended shift angle can be manufactured.

It is preferable that an alignment mark be formed on a protection sheet for the polarizing plate, for example. Like in the aforementioned cutting of the polarizing plate, when the alignment mark is to be formed, the direction of the optical axis of each of the polarizing plate and the biaxial phase difference film material is specified accurately. Then, the alignment mark is arranged in a position opposite to the specified direction of the optical axis in terms of a certain shift angle and a direction.

Like in the case where the end side of the outer shape of each of the polarizing plate and the biaxial phase difference film is used as a reference, the polarizing plate and the biaxial phase difference film may be aligned and bonded using the shifted alignment mark as a reference such that the respective end sides of the outer shapes of the polarizing plate and the biaxial phase difference film become parallel as accurately as possible to the end side of the outer shape of the quadrilateral substrate of the liquid crystal cell.

The preferred embodiments of the present invention can be combined freely within the scope of the invention. Further, any component of each of the preferred embodiments can be changed or omitted, where appropriate.

While the invention has been shown and described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is therefore understood that numerous modifications and variations can be devised without departing from the scope of the invention.

What is claimed is:

1. A liquid crystal panel comprising an array substrate, a counter substrate arranged to face said array substrate, and a liquid crystal layer interposed between said array substrate and said counter substrate, said array substrate including multiple switching elements arranged in a matrix, a pixel electrode connected to said switching elements, and a counter electrode capable of forming a fringe electric field between said counter electrode and said pixel electrode, said switching elements, said pixel electrode, and said counter electrode being provided on an insulating substrate, wherein

one of said pixel electrode and said counter electrode is formed as a slit electrode having a slit portion and the other of said pixel electrode and said counter electrode is stacked over said slit electrode at said insulating substrate side with respect to said slit electrode with an insulating film interposed therebetween,

said array substrate includes a biaxial phase difference film and an array substrate polarizing plate arranged in this order on a surface of said insulating substrate opposite a side thereof facing said liquid crystal layer,

said counter substrate includes a counter substrate polarizing plate arranged on a side of said counter substrate opposite a side thereof facing said liquid crystal layer,

said slit portion of said slit electrode extends in a direction forming an angle exceeding 0° and not exceeding 15° relative to a horizontal direction of said liquid crystal panel in use,

a pretilt angle of a liquid crystal molecule forming said liquid crystal layer on the side of said array substrate is formed such that said liquid crystal molecule goes away from said array substrate in a direction to the right when viewed from a position facing a display surface of said liquid crystal panel, said direction to the right defining said horizontal direction, and said pretilt angle on the side of said counter substrate is formed such that said liquid crystal molecule goes away from said counter substrate in a direction to the left when viewed from a position facing said display surface of said liquid crystal panel, said direction to the left defining said horizontal direction, and

one of a direction of a delay phase axis of said biaxial phase difference film and a direction of an absorption axis of said array substrate polarizing plate is arranged in a position rotated clockwise in an angular range from over 0° to 1° from said horizontal direction or one of a direction of an absorption axis of said counter substrate polarizing plate and an alignment direction of said liquid crystal molecule is arranged in a position rotated anticlockwise in an angular range from over 0° to 1° from said horizontal direction.

2. The liquid crystal panel according to claim **1**, wherein said insulating substrate, said biaxial phase difference film, said array substrate polarizing plate, and said counter substrate polarizing plate are each formed into a quadrilateral configuration, and

each of said biaxial phase difference film, said array substrate polarizing plate, and said counter substrate polarizing plate has at least one end side of an outer shape thereof arranged parallel to at least one end side of an outer shape of said insulating substrate.

3. A liquid crystal display device comprising:

the liquid crystal panel as recited in claim **1**; and

an illumination unit to illuminate said liquid crystal panel.

* * * * *